

DOCUMENT RESUME

ED 482 909

SE 068 175

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TITLE Exemplary Science Benchmarks among the Seven States in the Central Region.
INSTITUTION Mid-Continent Research for Education and Learning, Aurora, CO.
SPONS AGENCY Department of Education, Washington, DC.
PUB DATE 2003-06-01
NOTE 20p.
CONTRACT ED-01-CO-0006
AVAILABLE FROM McREL, 2550 S. Parker Road, Suite 500, Aurora, CO 80014. Tel: 303-337-0990; Fax: 303-337-3005; Web site: www.mcrel.org.
PUB TYPE Reports - Descriptive (141)
EDRS PRICE EDRS Price MF01/PC01 Plus Postage.
DESCRIPTORS Academic Achievement; Elementary Secondary Education; Instructional Materials; *National Standards; Science Curriculum; *Science Instruction; *State Standards

ABSTRACT

This study identifies a core set of exemplary standards and benchmarks that are accepted by a significant number of educators in the Mid-continent Research for Education and Learning (McREL) region. Specifically, the study provides a list of the knowledge and skills expected of students in most or all states in the Central Region (comprised of Colorado, Kansas, Missouri, Nebraska, North Dakota, South Dakota, and Wyoming) that are also found in state standards documents that have been rated as exemplary by national organizations. In short, this list of standards and benchmarks embodies content that is highly valued nationally as well as within the Central Region. Such a list may assist educators in the region in sharing educational materials that support the academic content they all value. Current school reform efforts create a significant demand for curriculum materials that help students achieve specific and worthwhile standards. A shared set of standards and benchmarks should provide educators with a useful focus for their efforts to find or share high-quality materials that support exemplary standards and benchmarks. (Author)

ED 482 909

EXEMPLARY SCIENCE BENCHMARKS AMONG THE SEVEN STATES IN THE CENTRAL REGION

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Regional Educational Laboratory
Contract #ED-01-CO-0006
Deliverable #2003-01

Prepared for
Institute of Education Sciences
U.S. Department of Education
Washington, D.C. 20208

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June 1, 2003

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PURPOSE

This study identifies a core set of exemplary standards and benchmarks that are accepted by a significant number of educators in the McREL region. Specifically, the study provides a list of the knowledge and skills expected of students in most or all states in the Central Region (comprised of Colorado, Kansas, Missouri, Nebraska, North Dakota, South Dakota, and Wyoming) that are also found in state standards documents that have been rated as exemplary by national organizations.

In short, this list of standards and benchmarks embodies content that is highly valued nationally as well as within the Central Region. Such a list may assist educators in the region in sharing educational materials that support the academic content they all value. Current school reform efforts create a significant demand for curriculum materials that help students achieve specific and worthwhile standards. A shared set of standards and benchmarks should provide educators with a useful focus for their efforts to find or share high-quality materials that support exemplary standards and benchmarks.

METHOD

In order to ensure that the list of standards and benchmarks produced by this study would be considered exemplary, analysts selected as a reference document a study that identified highly rated science standards and benchmarks. The study (hereafter, the McREL study) was the result of a project undertaken at McREL in 1999 (Kendall, Snyder, Schintgen, Wahlquist, & Marzano).

Briefly, that project identified the science content present in documents from a handful of states that were highly rated by national organizations for the quality of their standards. It was reasoned that such a list of content represented what reputable national organizations (specifically, the American Federation of Teachers, the Council for Basic Education, and the Fordham Foundation) deemed to be model content in science (see the McREL study for a complete discussion of the project and its results).

Against this reference set of standards and benchmarks, state standards were reviewed to determine what content from the reference document was also commonly valued among the seven states in the Central Region. The following state standards documents were used in this study:

- Colorado Model Content Standards: Science (1995, November)
- Kansas Science Education Standards (2001, February)
- Missouri's Framework for Curriculum Development in Science K-12 (1996)
- Nebraska Science Standards (1998, May)
- North Dakota Standards and Benchmarks: Content Standards: Science (2002, November)
- South Dakota Science Standards (1999, June)
- Wyoming Science Standards (1999, April)

The seven state standards documents were compared to the exemplary benchmarks identified in the McREL study. The process of comparison was first undertaken independently by two analysts. Each analyst determined whether the content in the reference document could also be found in each of the state documents. At the end of the review, then, each analyst had determined which states in the Central Region shared the same exemplary content. For the purpose of the analysis, benchmarks were considered comparable if they appeared within two grades above or below the grade range of the McREL study.

When both analyses were completed, a third analyst then compared the reviews in order to determine which discrepancies were significant. If the disparity between raters on any item was greater than three states (out of the seven states reviewed), the original raters conferred regarding that item in order to resolve the disparity to within at least two states, before it was submitted for resolution by the third analyst.

The third analyst then resolved only significant discrepancies, specifically those discrepancies that would have a bearing on whether the identified content would be included in the final list of commonly found benchmarks. In other words, if resolving a disparate evaluation by the analysts would have no effect on whether the content was included, such a disagreement was left unresolved.

The threshold for inclusion of content in the list was determined after a preliminary review of the results, which is discussed in the following section. Once identified, all significant discrepancies were resolved when the third rater conducted the comparison, using the same criteria as the first two raters.

THRESHOLD FOR INCLUSION

A preliminary comparison of the two independent reviews of state standards against the reference document indicated that if the list of standards and benchmarks was restricted to only content found to be common across every state, then less than a quarter of the potential number of benchmarks would be identified. However, it was found that if the content to be identified was expanded to content common to *any six or all seven* states, then the number of common benchmarks was considerably expanded. Over half the benchmarks in the reference study would be identified.

Specifically, 22 benchmarks were found to be common to all seven states in the preliminary analysis, while 50 of the 95 benchmarks, after the final analysis and resolution of discrepant ratings, were common among six or seven states.

The threshold was not further lowered to content that might be present in *any five of seven states* for two reasons. First, the utility of the list for all states would be compromised if a significant number of the benchmarks presented in the list were found in only five states. It was calculated that about a quarter of the benchmarks would be common to only five states. Second, it would be difficult to describe the list as representative of states in the region if such a large portion of benchmarks was found in just 71 percent (five of seven) of the states. Conversely, if the list were restricted to the

commonalities found in six or more states, the list of benchmarks would represent approximately 86 percent of the states in the Central Region.

PRIMARY FINDINGS

Of the exemplary benchmarks listed in the reference document, approximately 52% were found to be present in at least six of the seven states in the Central Region. These benchmarks appeared across all the standards that organize science content of the reference document. It is of interest to note that standard 14, "Understands the nature of scientific inquiry," was unusual in that it was the sole standard in which the content of every benchmark was found to be represented in all seven state standards documents of the region.

EXEMPLARY SCIENCE BENCHMARKS COMMONLY FOUND IN THE CENTRAL REGION

The exemplary benchmarks commonly found in the Central Region are presented in this section. The benchmarks are organized by the standards that were used in the reference document. The 14 standards listed in Table 1 do not differ significantly from the kinds of standards found in most science documents, including the state documents reviewed here. These standards serve as useful organizers of information; the benchmarks provide the content of primary interest.

The seven state standards documents listed in Table 2 were compared against a set of exemplary benchmarks in science. The benchmarks that begin on page 5, which are organized by standard, were found to be present in highly rated standards documents and in standards documents of at least six of seven states in the Central Region. Benchmarks within the seven state documents were considered comparable to benchmarks in the reference document only if the same or similar content appeared within two grades above or below the same grade band.

The benchmarks are presented in the format of grade ranges K-2, 3-5, 6-8, and 9-12, which is the structure of the reference document. Table 2 shows the variation of grade ranges used in the seven state documents.

Table 1. Science Standards that Organize the Exemplary Benchmarks Commonly Found in the Central Region

Earth and Space Sciences
1. Understands basic features of the Earth 2. Understands basic Earth processes 3. Understands essential ideas about the composition and structure of the universe and the Earth's place in it
Life Sciences
4. Knows about the diversity and unity that characterize life 5. Understands the genetic basis for the transfer of biological characteristics from one generation to the next 6. Knows the general structure and functions of cells in organisms 7. Understands how species depend on one another and on the environment for survival 8. Understands the cycling of matter and flow of energy through the living environment 9. Understands the basic concepts of the evolution of species
Physical Sciences
10. Understands basic concepts about the structure and properties of matter 11. Understands energy types, sources, and conversions, and their relationship to heat and temperature 12. Understands motion and the principles that explain it 13. Knows the kinds of forces that exist between objects and within atoms
Nature of Science
14. Understands the nature of scientific inquiry 15. Understands the scientific enterprise

Note: Standards with benchmarks in at least six of the seven Central Region's state standards documents

Table 2. Benchmark Grade Ranges Used by the Seven Central Region States

State Document	Benchmark Grade Range
<i>Colorado Model Content Standards: Science</i>	K-4, 5-8, 9-12
<i>Kansas Science Education Standards</i>	K-2, 3-4, 5-8, 9-12 ¹
<i>Missouri's Framework for Curriculum Development in Science K-12</i>	K-4, 5-8, 9-12
<i>Nebraska Science Standards</i>	K-1, 4, 8, 12
<i>North Dakota Standards and Benchmarks: Content Standards: Science</i>	4, 8, 12
<i>South Dakota Science Standards</i>	K, 1, 2, 3, 4, 5, 6, 7, 8, 9-12
<i>Wyoming Science Standards</i>	4, 8, 11

Earth and Space Sciences

Standard 1. Understands basic features of the Earth

Grades K-2

- Understands that short-term weather conditions can change daily but that each season is characterized by general weather patterns; these changes in weather influence plant, animal, and human activities

Grades 3-5

Insufficient evidence to support benchmarks at this level¹

Grades 6-8

- Knows the composition and structure of the Earth's atmosphere (e.g., temperature and pressure in different layers of the atmosphere, circulation of air masses, fronts) and its role in weather patterns

¹ This notation appears wherever the reference document contained no benchmarks at a given level.

Grades 9–12

- Understands heat and energy transfer in and out of the atmosphere and its involvement in weather and climate (e.g., radiation, conduction, convection/advection)
- Understands the factors that influence water quality, supply, use, reuse, recycling, conservation, and management

Standard 2. Understands basic Earth processes

Grades K–2

Insufficient evidence to support benchmarks at this level

Grades 3–5

- Knows the composition and properties of soils (e.g., components of soil such as weathered rock, living organisms, plant and animal remains; properties of soil such as color, texture, capacity to retain water, ability to support plant growth)
- Knows how features on the Earth's surface are constantly changed by a combination of slow and rapid processes (e.g., weathering, erosion, transport, deposition of sediment by waves, wind, water, and ice; landslides, volcanic eruptions, earthquakes, floods, ice and snow storms, hurricanes, tornadoes, droughts)

Grades 6–8

No commonalities found among six or more states

Grades 9–12

- Understands the concept of plate tectonics and the evidence that supports it (including structural, geophysical, and paleontological evidence)

Standard 3. Understands essential ideas about the composition and structure of the universe and the Earth's place in it

Grades K–2

- Knows the basic patterns of objects in the sky (e.g., the Sun appears every day; the Moon appears sometimes at night and sometimes during the day; the Sun and Moon appear to move from east to west across the sky; the Sun's position in the sky changes through the seasons; the Moon appears to change shape over the course of a month; stars move slowly across the sky)

Grades 3–5

No commonalities found among six or more states

Grades 6–8

- Knows the characteristics and movement patterns of objects in the Solar System (e.g., sun, planets, moons, asteroids, comets, meteors)

Grades 9–12

- Knows the ongoing processes involved in star formation and destruction (e.g., stars condense out of clouds of molecules of the lightest elements; nuclear fusion of light elements into heavier ones occurs in the stars' extremely hot, dense cores, releasing great amounts of energy; some stars eventually explode, producing clouds of material from which new stars and planets condense)

Life Sciences

Standard 4. Knows about the diversity and unity that characterize life

Grades K–2

- Knows that plants and animals have features that help them live in different environments
- Knows that plants and animals progress through life cycles of birth, growth and development, reproduction, and death; the details of these life cycles are different for different organisms (e.g., frog, butterfly, cat, dandelion)

Grades 3–5

No commonalities found among six or more states

Grades 6–8

- Knows ways in which living things can be classified (e.g., taxonomic groups of plants, animals, and fungi; groups based on the details of organisms' internal and external features; groups based on functions served within an ecosystem)

Grades 9–12

No commonalities found among six or more states

Standard 5. Understands the genetic basis for the transfer of biological characteristics from one generation to the next

Grades K-2

No commonalities found among six or more states

Grades 3-5

No commonalities found among six or more states

Grades 6-8

- Understands the similarities and differences between sexual and asexual reproduction

Grades 9-12

- Knows the chemical and structural properties of DNA and the role of DNA in heredity and protein synthesis (e.g., DNA synthesis, translation, transcription; mRNA and codons; effect of mutations)
- Understands Mendel's laws of heredity (e.g., segregation and independent assortment)

Standard 6. Knows the general structure and functions of cells in organisms

Grades K-2

- Knows the basic needs of plants and animals (e.g., air, water, nutrients, light or food)

Grades 3-5

- Knows that living organisms have distinct structures and body systems that serve specific functions in growth, survival, and reproduction (e.g., body structures for walking, flying, swimming; digestive, circulatory, and skeletal systems in vertebrates, invertebrates, unicellular organisms, and plants)

Grades 6-8

- Knows the basic components and functions of cells and the differences among various types of cells (e.g., plant, animal, and prokaryotic; muscle, nerve, bone)
- Knows that multicellular organisms have a variety of specialized cells, tissues, organs, and organ systems that perform specialized functions (e.g., respiration, circulation, digestion, excretion, reproduction, movement, coordination, protection from disease)

Grades 9–12

No commonalities found among six or more states

Standard 7. Understands how species depend on one another and on the environment for survival

Grades K–2

Insufficient evidence to support benchmarks at this level

Grades 3–5

No commonalities found among six or more states

Grades 6–8

- Knows factors that affect the number and types of organisms an ecosystem can support (e.g., available resources; abiotic factors such as quantity of light and water, range of temperatures, and soil composition; disease; competition from other organisms within the ecosystem; predation)

Grades 9–12

- Knows ways in which humans can alter the equilibrium in ecosystems, causing irreversible effects (e.g., human population growth, technology, and consumption; human destruction of habitats through direct harvesting, pollution, and atmospheric changes)

Standard 8. Understands the cycling of matter and flow of energy through the living environment

Grades K–2

Insufficient evidence to support benchmarks at this level

Grades 3–5

Insufficient evidence to support benchmarks at this level

Grades 6–8

- Knows how matter is recycled within ecosystems (e.g., matter is transferred from one organism to another repeatedly, and between organisms and their physical environment; the total amount of matter remains constant, even though its form and location change)

Grades 9–12

- Knows that as matter and energy flow through different levels of organization in living systems and between living systems and the physical environment, chemical elements (e.g., carbon, nitrogen) are recombined in different ways

Standard 9. Understands the basic concepts of the evolution of species

Grades K–2

Insufficient evidence to support benchmarks at this level

Grades 3–5

- Knows that fossils can be compared to one another and to living organisms to observe their similarities and differences

Grades 6–8

Insufficient evidence to support benchmarks at this level

Grades 9–12

- Understands the concept of natural selection (e.g., when an environment changes, some inherited characteristics become more or less advantageous or neutral, and chance alone can result in characteristics having no survival or reproductive value)
- Understands the theory of biological evolution (e.g., the Earth's present-day life forms evolved from earlier, distinctly different species)

Physical Sciences

Standard 10. Understands basic concepts about the structure and properties of matter

Grades K–2

- Knows that different objects have many different observable characteristics (e.g., material composition, color, size, shape, weight, texture) and can be sorted and classified by these characteristics

Grades 3–5

- Knows that substances can be classified by their physical and chemical properties (e.g., conductivity, magnetism, density, solubility, boiling and melting points)

- Knows that matter has different states (solid, liquid, gas) and that each state has distinct physical properties; some common materials such as water can be changed from one state to another by heating or cooling

Grades 6–8

- Understands the conservation of matter in physical and chemical change (e.g., regardless of how substances within a closed system interact with one another, the total weight of the system remains the same; the same number of atoms weighs the same, no matter how the atoms are arranged)
- Understands the nature of the physical and chemical properties of atoms, matter, molecules, elements, compounds, mixtures, and solutions

Grades 9–12

No commonalities found among six or more states

Standard 11. Understands energy types, sources, and conversions, and their relationship to heat and temperature

Grades K–2

- Knows that the Sun supplies heat and light to the Earth

Grades 3–5

No commonalities found among six or more states

Grades 6–8

- Understands the law of conservation of energy (i.e., energy cannot be created or destroyed but only changed from one form to another)
- Understands that heat can be transferred from warmer objects or areas to cooler ones through conduction, convection, and radiation until both objects reach the same temperature (e.g., the distribution of heat in the atmosphere and oceans by convection currents)
- Knows that most physical and chemical reactions involve a transfer of energy (e.g., heat, light, mechanical motion, electricity)

Grades 9–12

- Understands the distinction between kinetic and potential energy

Standard 12. Understands motion and the principles that explain it

Grades K-2

- Knows that vibrating objects produce sound, which can be characterized by its pitch and volume
- Knows that the position and motion of an object can be changed by pushing or pulling (i.e., by forces)

Grades 3-5

No commonalities found among six or more states

Grades 6-8

- Understands Newton's laws of motion (e.g., the effects of two or more forces on an object at once is the cumulative effect of all the forces; with balanced forces or in the absence of a force, there is no change in motion, whereas unbalanced forces such as friction will cause changes in the speed and/or direction of an object's motion)

Grades 9-12

Insufficient evidence to support benchmarks at this level

Standard 13. Knows the kinds of forces that exist between objects and within atoms

No commonalities found among six or more states

Nature of Science	
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Standard 14. Understands the nature of scientific inquiry

Grades K-2

- Formulates questions about the natural world, seeks answers by making careful observations, and communicates observations orally and in drawings
- Knows how to use simple tools (e.g., thermometers, magnifiers, rulers, balances, watches) to gather information and extend the senses

Grades 3-5

- Plans and conducts simple investigations (i.e., develops a testable question, makes systematic observations, conducts simple experiments to answer questions, develops a logical conclusion, and communicates findings to others)

- Uses appropriate tools and simple equipment to gather scientific data and extend the senses (e.g., rulers, thermometers, magnifiers, microscopes, calculators)

Grades 6–8

- Designs and conducts scientific investigations (i.e., formulates hypotheses, designs and executes investigations, interprets data, synthesizes evidence into explanations, proposes alternative explanations for observations, critiques explanations and procedures, and communicates steps and results from an investigation in written reports and verbal presentations)

Grades 9–12

- Designs and conducts scientific investigations (i.e., formulates testable hypotheses; identifies and clarifies the method, controls, and variables; organizes, displays, and analyzes data; revises methods, explanations, and hypotheses; presents the results; and receives critical response from others)

Standard 15. Understands the scientific enterprise

Grades K–2

- Knows that people invent new technological devices to solve problems in everyday life (e.g., zippers, paper clips, telephones, microwave ovens)

Grades 3–5

- Understands the interrelationship between science and technology (e.g., science creates opportunities for technological developments; new technologies allow scientific investigations that were previously impossible to be conducted)

Grades 6–8

- Knows ways in which science and society influence each other (e.g., scientific knowledge and the procedures used by scientists influence the way many individuals think about themselves, others, and the environment; technology can contribute to the solution of an individual or community problem; social and economic forces strongly influence which science and technology programs are pursued, invested in, and used)

Grades 9–12

- Knows that throughout history, diverse cultures have developed scientific ideas and solved human problems through technology

ADDITIONAL FINDINGS

As anticipated, during the preliminary comparison of the independent reviews, it became clear that the study revealed other information that might be of interest to educators in the region. Specifically, a number of benchmarks that were present in the reference document, and therefore viewed as important science content in highly rated standards documents, were found to be either missing from all state documents or present in just one or two states.

EXEMPLARY SCIENCE BENCHMARKS RARELY FOUND IN THE CENTRAL REGION

Seven state standards documents were compared against a set of exemplary standards in science. This section provides a list of benchmarks, organized by standard (see Table 3), that were found in the reference document of exemplary standards, but appeared in just two or fewer state standards documents in the Central Region.

Table 3. Science Standards that Organize the Exemplary Benchmarks Rarely Found in the Central Region

Life Sciences
1. Knows the general structure and functions of cells in organisms
2. Understands the cycling of matter and flow of energy through the living environment
Physical Sciences
3. Understands basic concepts about the structure and properties of matter

Note: Standards with benchmarks in two or fewer of the Central Region's state standards documents

Life Sciences

Standard 1. Knows the general structure and functions of cells in organisms

Grades 9-12

- Knows the structures of proteins (e.g., long, usually folded chain molecules made of specific sequences of amino acids coded by the DNA)

Standard 2. Understands the cycling of matter and flow of energy through the living environment

Grades 9–12

- Knows how the amount of life an environment can support is limited by the availability of matter and energy and the ability of the ecosystem to recycle materials

Physical Sciences

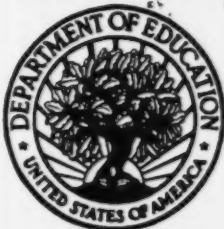
Standard 3. Understands basic concepts about the structure and properties of matter

Grades 9–12

- Knows that atoms may be bonded together into distinct molecules which may form solids by building up repeating patterns (e.g., crystal structures, long chain polymers)

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